

2019 PROJECT OF THE YEAR

TRANSPORTATION CATEGORY

The Île-aux-Tourtes Bridge Rehabilitation

MONTREAL, QUEBEC, CANADA

SUBMITTED BY SIKA CANADA, INC.



Fig. 1: The Île-aux-Tourtes Bridge

INTRODUCTION

The Île-aux-Tourtes Bridge is a highway bridge (Fig. 1) linking Vaudreuil-Dorion to Senneville, crossing Girwood Island and lac des Deux-Montagnes (lake), an extension of the Ottawa River to the west of the island of Montreal. It connects the administrative regions of Montérégie and Montreal in the province of Quebec, Canada.

The bridge is part of Highway 40 and forms part of the Trans-Canada Highway. It has six lanes of traffic, three lanes per direction, which are separated by a median barrier. It is estimated that about 60,000 vehicles use it per day at an annual average of 21.9 million vehicles.

The bridge was built between 1962 and 1965. The total bridge length is about 1.25 miles (2 km)

and consists of two types of structural systems: 8 spans of reinforced concrete girders and 35 spans of prestressed concrete girders.

In 2017, the 54-year-old structure exhibited signs of deterioration at some girders and slabs, and the Ministry of Transportation of Quebec (MTQ) contracted for the reinforcing of two post-tension box girders over the Île-aux-Tourtes Bridge seaway. The construction segment began in mid-2017 and was completed in early August 2018.

SPECIAL CHARACTERISTICS

- Repair of two prestressed edge box girders with internal prestressed cables showing significant corrosion, concrete cracking, and delamination at certain locations. The strengthening of these two bridge girders was a priority;



Fig. 2: Working platforms over the maritime corridor

- The bridge did not have a waterproofing deck membrane because it was not mandatory to be installed at the time of construction;
- The concrete prestressed box girder seaway spans (x2) suffered settlement from the shoring system at the time of construction which generated negative vertical grade. Additional asphalt was required to obtain the proper design vertical grade, increasing the bridge dead load which had to be carried by strengthening of the girders;
- In 2000, the bridge deck had an enlargement of about 3.3 ft (1 m) on both sides of the bridge which had to be taken into account in the bridge supplemental dead loads; and
- Shear strengthening of the box girder dap ends combined with the shear and flexural strengthening of both girders.

CHALLENGES

- Designing a high strength girder reinforcement with minimal dead load increase;
- Repairing the damaged girders before strengthening could be achieved because the initial concrete demolition and drilling of anchor holes adds further weakness to the structure initially;
- Maintaining the seaway operational throughout the work without vessel obstruction (Fig. 2); and
- Maintaining three lanes open in the rush hour direction.

INNOVATIONS

The reinforcing consisted of two steps:

- Step 1:** Girder and dap end shear strengthening by adding carbon fiber reinforced polymer (CFRP).
- Step 2:** Girder flexural strengthening by adding external post-tensioning (EPT).

The design had to be carefully planned to overcome the lack of capacity caused by the present girder condition. Several construction stages were required to gradually strengthen the girders by minimizing the risks during each step. This was done using various work zones.

The CFRP installed in the negative bending moment location was mechanically anchored as recommended by various manufacturer CFRP design guides. All CFRP strips in this zone were anchored by an innovative system of steel anchor plates and steel rods. The anchor rod holes were produced using a vertical and horizontal drilling template due to the high amount of required precision and number of holes.

3D girder scanning was used to generate the data required for the production of the 256 anchor plate drawings. The fabrication and installation of the plates was carried out quickly and successfully without any on-site modification.



Fig. 3: Test beam



Fig. 4: Rebar and strand identification

The EPT blocks were designed in steel to minimize any dead load increase until the external post-tension was added, reducing the shear and bending moment of the girders. This procedure reduced the risk of further girder damage before the final post-tensioning could be carried out.

The steel geometry was more compact and lighter than the concrete blocks and were factory built instead of on-site construction, minimizing any on-site potential delays or quality issues.

The use of several technologies were required to add the correct amount of final EPT reflecting the non-homogeneous degradation of the girder internal prestressing cables:

- 3D scanner for accurate girder camber surveying before and during added EPT;
- Measurement of the internal stresses of concrete by slot stress;
- Strain gauges added to monitor girder strain variations during EPT which were converted into longitudinal stresses and added to initial internal girder stresses from the slot stress; and
- Installation of a strand tension load sensor in each of the active EPT blocks to confirm the final EPT and for future strand load monitoring.

GIRDER REHABILITATION

Test Beam

A small-scale girder section was produced in a factory to reproduce all girder work steps required (Fig. 3). This was specified by the designer to validate the contractor drilling template, hole preparation, 3D scanning, CFRP steel plate drawing, and the anchor plate installation. Once the test beam work was approved, the contractor started the on-site bridge rehabilitation work.

Rebar and Internal Prestressing Cable Detection

The internal steel rebars and prestressing cables were located by radar detection to prevent damaging them during the drilling operation in the girder web, flanges, and top slab. All anchor plate holes and EPT steel block anchor hole locations were identified prior to the drilling operation (Fig. 4). This step was crucial because the CFRP strip locations were identified along with the required anchor holes for each plate.

Girder and Slab Repair

The areas to be repaired were prepared to an ICRI surface profile of CSP 6 to 10. Prior to concreting, an anti-corrosion coating was used on the previously exposed rebar. High performance mortar was then used for girder repairs (Fig. 5 and 6). Web thickening locations for future EPT steel blocks were made with self-leveling concrete using mixed packaged materials to avoid a long curing process. CFRP strips were applied within 36-48 hours after concrete placement.



Fig. 5: Typical lower flange girder concrete demolition



Fig. 6: Repaired girder using mortar concrete



Fig. 7: Underside heavy duty slab repair prior to adding forms, concrete and steel deck and transverse beams



Fig. 8: Crack injection preparation



Fig. 9: Steel CFRP anchor plate horizontal hole drilling

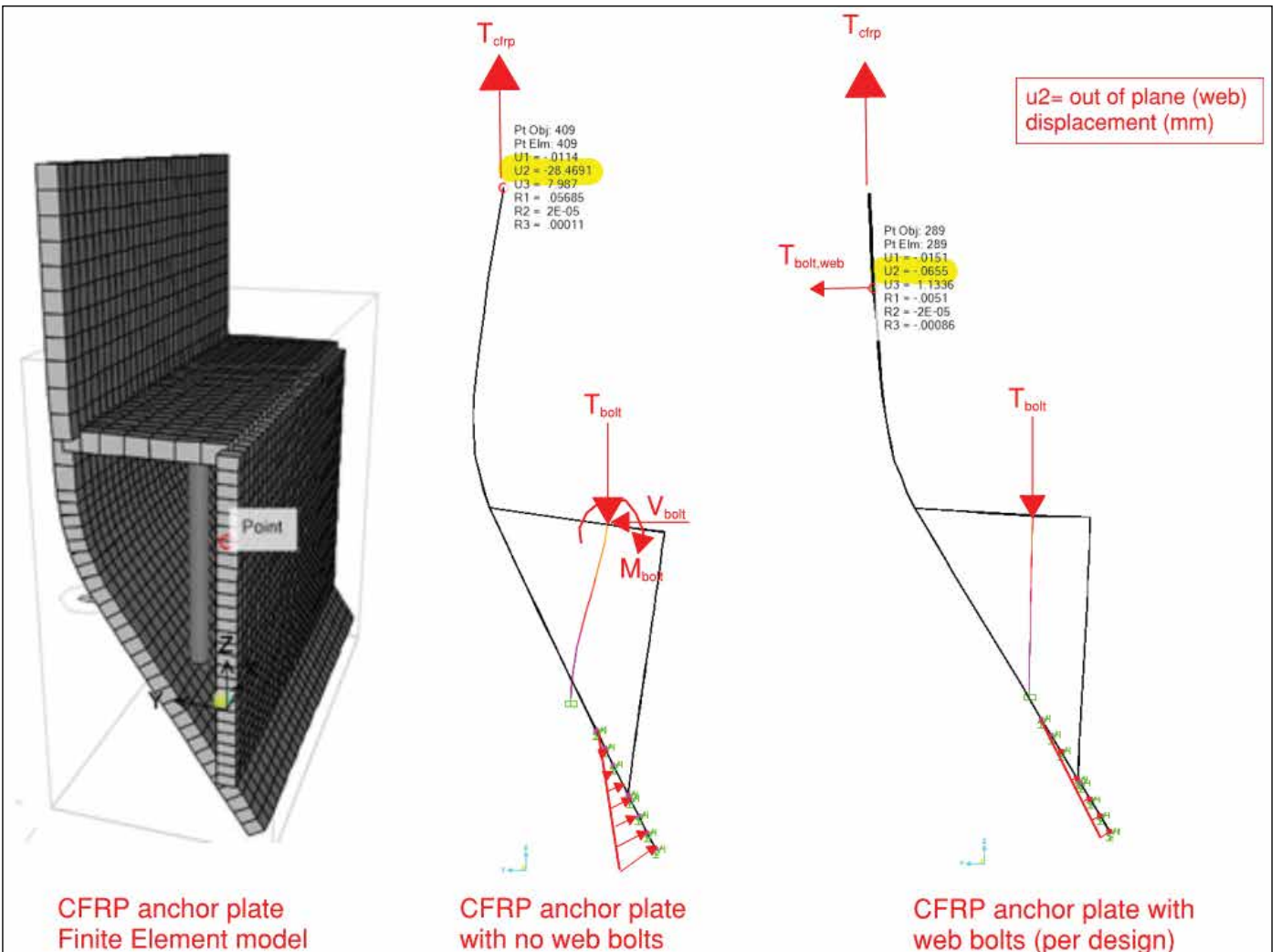


Fig. 10: 3D Steel CFRP anchor plate analysis model

Heavy-duty slab repair utilized ultra-fast hardening self-leveling concrete placed from the top of the deck. This limited the bridge lane closure at night to about 30 minutes. Several areas of the slab had to be repaired by creating an extra thickness on the underside of the slab (Fig. 7). Cracks in the bridge slab and girders had to be repaired before the low-viscosity epoxy crack injection (Fig. 8).

Anchoring Plate and Blocks

1-1/8 in (28.6 mm) diameter vertical holes were drilled into the girder top and lower flanges (Fig. 9) to insert 1 in (25.4 mm) diameter anchor rods (4 required per CFRP anchor plate). The vertical anchor rods were designed to carry the CFRP strip tension load while the horizontal anchor rods were designed only to prevent the CFRP plate from web normal displacement (secondary bending due to vertical rod offset from web plane). These horizontal holes were filled with grease to only carry tension loading with no shear loads from CFRP strips. A total of 1,024 vertical anchor rods and 512 horizontal rods were required for the installation of all CFRP anchor plates. Holes were oversized to facilitate the on-site plate installation and were designed in tension only.

Plates were designed using the latest 3D technology, design software, and 3D scanning to ensure proper fit in the field (Fig. 10 and 11). This step was important to assure that anchor plates matched the existing girder geometry which differed at many locations due to previous damage or repairs. Plates were bonded with a thixotropic epoxy to provide a contact surface to the CFRP fabric before torquing bolts (Fig. 12).

It is important to note that the positive moment zone did not use any mechanical anchors. Various horizontal CFRP strips were used to create an anchor at various specific locations. This configuration was previously tested and showed shear capacity increase of more than 50% from the original girder condition, which was found sufficient for the girder condition.

CFRP Reinforcement

A very high density fabric (1385 g/sm) was used for shear strengthening in both negative and positive moments. The entire length of the two girders was reinforced with CFRP fabric (Fig. 13). The girder shear CFRP strengthening used 2 plies of fabrics while the dap ends used up to 6 plies due to the higher required load capacity.

External Post-Tensioning (EPT)

The EPT was provided to add the required flexure capacity for actual and assumed future girder deterioration and improved the girder shear capacity by adding axial beneficial compression (while not the main goal). The EPT was composed of two steel blocks with each carrying 22 x T15 greased sheath strands with multiple corrosion protection systems for high durability due to its primary function (Fig. 14 and 15).

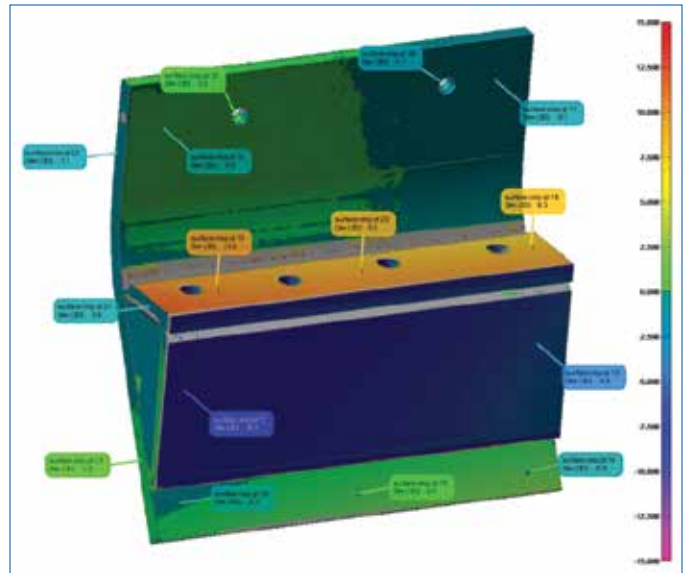


Fig. 11: 3D scanning of parts to generate 3D CAD models to correspond with girder profile



Fig. 12: Steel CFRP anchor plates



Fig. 13: Installed CFRP strips



Fig. 14: External post-tensioning system



Fig. 15: External view of girder after completion of work



Fig. 16: Spray applied waterproofing deck membrane application

Crack Monitoring on Side Barrier

The side barrier at the pier location (maximum negative bending moment) had multiple cracks. This was the result of the loss in flexural capacity of the edge girders. The vertical cracks extended along the girder web and were monitored on a daily basis to assure the proper work steps. The anticipated initial design steps were changed on-site to accelerate the construction process and ensure the final external post tensioning could be applied prior to an accelerating potential cracking mode.

Concrete Slab Waterproofing Membrane

A liquid waterproofing membrane (Fig. 16) and new pavement were added to protect the new girder rehabilitation and avoid de-icing salts from penetrating the new CFRP repair from deck cracks and preventing premature concrete delamination and additional internal prestressing cable corrosion. This assures the required dry surface condition for the CFRP installation on the girder webs and near the top slab location.

CONCLUSION

The Île-aux-Tourtes Bridge is an economically vital structure for Greater Montreal and the entire province of Québec because it is part of the Trans-Canada Highway and main entrance from/to the province of Ontario. From a sustainability point of view, the work has extended the life of the existing girders for an additional 15 years. A combination of the latest technologies in construction with the expertise of the concrete refurbishment industry made this project a success and an example for future bridge rehabilitation projects.

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